



CHEMICAL HAZARD SURVEY

Canadian Centre for Occupational Health and Safety

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Non-Crystalline Silicas

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SCOPE OF THE DOCUMENT

This document focuses on the hazards of non-crystalline silicas. The toxicity of non-crystalline silicas is described. The relevance and perspective of the information for the workplace is emphasized. Special attention is given to the main hazard presented by non-crystalline silicas.

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I. MAIN HAZARD

The main hazard of non-crystalline silicas is their potential for scarring the lungs after many years of exposure. It is thought that the lung scarring is caused by crystalline silica. The crystalline silica is present as a contaminant in naturally occurring non-crystalline silica or as a by-product in the manufacture of non-crystalline silica. Human studies suggest that as long as the crystalline silica content is below about 1 per cent the hazard of non-crystalline silicas is low. However, recent animal experiments suggest that the toxic effects of non-crystalline silicas cannot be completely accounted for by the presence of crystalline silica. Until these effects are more clearly understood exposure to non-crystalline silicas should be minimized.

II. OCCUPATIONAL EXPOSURES

Silica, which occurs naturally as quartz, is the most common mineral in the earth's crust. All silicas are made up of units of one silicon atom linked to four oxygen atoms. These units are joined to each other to form an endless network. In crystalline silicas the units are arranged in a regular pattern. In non-crystalline silicas these units are arranged randomly, leading to their common name "amorphous" (shapeless) silicas⁽¹⁾.

This summary discusses the hazards of non-crystalline silicas. The hazards of crystalline silica are discussed in another summary⁽²⁾.

Non-crystalline or amorphous silicas occur naturally as diatomaceous earth or as man-made substances.

Diatomaceous earth or diatomite is made of the skeletons of prehistoric sea creatures. It is the most common form of non-crystalline or amorphous silica. For some industrial uses diatomaceous earth is heated to produce calcined diatomaceous earth. This process converts some of the non-crystalline silica into crystalline silica. Sometimes alkaline chemicals are added during the heating process to produce flux-calcined diatomaceous earth. The fluxing process, either with chemicals and heat or with heat alone, transforms some of the non-crystalline silica into crystalline silica.

Synthetic, or man-made non-crystalline silicas include silica gel, precipitated silica, fumed silica and fused silica. These are widely used in industry as drying agents, thickeners, catalysts, fillers and surface coatings⁽¹⁾. Another type of non-crystalline silica is silica fume or condensed silica fume which is a by-product from silicon, or ferrosilicon manufacturing. Silica fume is used as an additive for concrete.

Inhalation is the major route of occupational exposure to non-crystalline silicas. Skin contact, eye contact and ingestion can also occur but produce only mild, temporary effects such as irritation.



III. HEALTH HAZARDS

Removal from the Body

When non-crystalline silica is inhaled, not all of the inhaled particles reach the lungs or remain there. Particles larger than about 10 microns in diameter (1 micron equals one millionth of a metre) are trapped by the moist mucous membranes in the nose and throat. Particles smaller than about 10 microns in diameter can by-pass the nose and throat. Some of these particles are trapped by tiny mucous covered hairs called cilia that line the large air passages in the upper part of the respiratory system. The cilia move back and forth to move the deposited particles back up the airways—much like an escalator—and into the throat to be swallowed or spit out.

Some dust particles remain suspended in the airways and so can bypass these protective systems and be deposited in the tiny air sacs where oxygen is transferred into the blood stream. In tissues surrounding these sacs, specialized cells called macrophages surround the particles and try to break them down or carry them back to the cilia where they can be transported out of the body. The removal of inhaled particles from the lungs is a slow process. Some particles may not be removed at all. It is the particles that remain in the lungs that may cause health effects.

Effects of Short-term Overexposure in Humans

Inhalation

Exposure to non-crystalline silicas for a short time may irritate the nose and throat.

Eye Contact

Exposure to non-crystalline silica may cause eye irritation.

Effects of Long-term Overexposure in Humans

The effects of long-term exposure appears to depend on the origin, purity and processing of the non-crystalline silicas⁽³⁻¹⁷⁾.

Diatomaceous Earth - Natural and Calcined

Pure non-crystalline silicas are rarely found. Naturally occurring diatomaceous earth usually contains some crystalline silica and is therefore weakly toxic. The crystalline silica content of diatomaceous earth can be increased by the calcining process.

It is thought that the presence of crystalline silica in natural and calcined diatomaceous earth accounts for the cases of scarring of the lungs (fibrosis) among workers or miners exposed for many years to these dusts^(3,4).

A review of European studies found that chest x-rays of workers exposed to high concentrations of natural diatomaceous earth for many years showed evidence of dust accumulation but the workers had little or no impairment of lung function⁽⁵⁾.



A major US study of diatomite mine and mill workers exposed to dust for up to 25 years or more, had similar findings^(6,7,8). There was no evidence of scarring of the lungs (fibrosis) among workers in the mines. On the other hand, there were many cases of severe lung fibrosis among the mill workers who were exposed to high levels of crystalline silica as a result of the calcining process.

The major problem with these studies is that neither the dust concentrations in the work areas nor the amount of crystalline silica in the dust were measured. Yet, these studies seem to support the conclusion that diatomaceous earth is not very harmful and that scarring of the lungs is due to the presence of crystalline silica.

Synthetic Non-Crystalline or Amorphous Silicas

Several types of synthetic amorphous silicas are manufactured, but the harmful effects of only a few of them have been studied.

In one study, chest x-rays and lung function tests were normal among workers with up to 8 years of exposure to precipitated amorphous silica⁽⁹⁾. There were also no harmful effects from long-term exposure to fumed silica⁽¹⁰⁾.

There is one report of lung scarring among workers exposed intermittently for 11 to 18 years to amorphous silica dust produced as a by-product of silicon metal production⁽¹¹⁾. In this process, crystalline silica (quartz) is vapourized by heating it to above its boiling point. The resulting silica was mainly non-crystalline but some crystalline silica was present and may have been the cause of the lung scarring.

Toxicity Data in Animals and Laboratory Tests

Animal experiments and laboratory tests may be useful in understanding and predicting toxic effects when there is little information about the effects of human exposure. But it has always been difficult to extend findings from animal experiments to humans. The most useful experiments are those in which the animals are exposed the same way as humans. In this case, the most meaningful experiments would be those in which animals inhale different non-crystalline silicas at different concentrations for various lengths of time. However, these experiments are costly and time-consuming because of the large number of animals needed.

Experiments in which dust samples are injected or implanted directly into the animal's lungs are more difficult to interpret. The natural defense mechanisms of the respiratory system are bypassed and the exposure is only to a single dose.

Diatomaceous Earth - Natural or Calcined

In an experiment with rats and guinea pigs, inhalation of natural diatomaceous earth without detectable crystalline silica produced no scarring of the lungs⁽¹²⁾. In another inhalation experiment, dogs, guinea pigs and rats were exposed to different concentrations of flux-calcined diatomaceous earth which contained about 60% crystalline silica. The animals were exposed daily for up to two and a half years, but showed no scarring of the lungs⁽¹³⁾.



In a different type of study, rats had samples of non-crystalline silica injected into their lungs. The effects of untreated diatomaceous earth were compared to the effects of calcined diatomaceous earth⁽¹⁴⁾. The diatomaceous earth was calcined by heating it at 800°C for 24 hours. The heated diatomaceous earth caused more scarring of the lungs than the untreated form, even though neither material contained detectable crystalline silica. This finding suggests that the heating process in some way changed the non-crystalline silica. The heated, or calcined diatomaceous earth became more harmful than the natural untreated form.

Precipitated Silica or Silica Gel

In one study, there was no scarring of the lungs in rats, guinea pigs and rabbits exposed to precipitated amorphous silica for up to two years at concentrations greater than 120 mg/m³⁽¹⁵⁾.

Fumed Silica

Inhalation exposure of rats, guinea pigs and rabbits to fumed silica caused some tissue reaction but no scarring of the lungs⁽¹⁵⁾. However, when the fumed silica was heated for 8 hours at 800°C, it caused severe scarring. The heated material did not contain any crystalline silica. Like the studies on diatomaceous earth, this study again suggests that the heating process changed the fumed silica into a more toxic material, but not crystalline silica.

Fused Silica

In one study, the toxicity of fused silica was compared to crystalline silicas (quartz, cristobalite and tridymite) by injecting the dusts into the respiratory systems of rats⁽¹⁶⁾. The fused silica caused fibrosis, but the fibrosis was not as severe as that caused by the crystalline silicas.

Other Laboratory Experiments

A recent series of experiments with macrophage cells taken from mice, raise further uncertainties about the action of non-crystalline silicas in the lungs⁽¹⁷⁾. It is thought that dusts which damage or kill macrophages can scar the lungs of animals and humans. Several kinds of natural and calcined diatomaceous earth samples were found to kill the mouse macrophages. It was expected that the calcined diatomaceous earth, which contained a small amount of crystalline silica, would be more toxic than the natural form. This was *not* the case. The natural diatomaceous earth was more toxic.

The macrophage experiments suggest that the crystalline content is probably not the only factor that determines whether non-crystalline silicas will cause scarring of the lungs.

IV. CHEMICAL REACTIVITY HAZARDS

Non-crystalline silicas are normally very unreactive. However, particularly strong oxidizing chemicals may react with non-crystalline silicas to cause a fire. These chemicals include fluorine, oxygen difluoride or chlorine trifluoride⁽⁴⁾.



V. EXPOSURE LIMITS

Many Canadian jurisdictions have exposure limits similar to the Threshold Limit Values (TLVs) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH).

The exposure limits that ACGIH recommend reflect the conclusion that non-crystalline silicas are not very toxic and any health effects are due to the presence of crystalline silica. Diatomaceous earth containing less than one percent quartz has been given the same exposure limit as nuisance dusts. ACGIH recommends that the exposure limits for crystalline silica (quartz) apply to calcined diatomaceous earth or diatomaceous earth containing more than one percent crystalline silica.

The following are the 1986-87 recommended TLVs⁽¹⁸⁾ for non-crystalline silicas:

Diatomaceous earth (uncalcined) containing less than one percent quartz	10 mg/m ³ as total dust
Precipitated silica containing less than one percent quartz	10 mg/m ³ as total dust
Silica gel containing less than one percent quartz	10 mg/m ³ as total dust
Fused silica	0.1 mg/m ³ as respirable dust

For calcined diatomaceous earth the individual exposure limits for crystalline silicas (quartz, cristobalite or tridymite) should be used.

For more information on crystalline silicas, consult CCOHS Chemical Hazard Summary no. 26⁽²⁾.

Contact the appropriate authority in your jurisdiction for details of the specific regulations which apply. Refer to ACGIH documentation for information on these recommended exposure limits⁽³⁾.

VI. EXPOSURE CONTROL

Engineering Controls

Engineering controls to reduce exposures are preferred. Methods include local exhaust ventilation, process or personnel enclosure, control of process conditions, and process modification⁽⁴⁾. Other control methods such as administrative controls or the use of personal protective equipment may also be required.

Specific ventilation designs to control exposure to non-crystalline silicas for some industrial processes are provided in the ACGIH "Industrial Ventilation : a Manual of Recommended Practice"⁽¹⁹⁾.



Respiratory Protection

If engineering controls and work practices are not effective in controlling exposure to non-crystalline silicas, then wear suitable, approved personal protective equipment⁽²⁰⁾.

If respiratory protection is required, institute a complete continuing respiratory protection program including selection, fit testing, training, maintenance, inspection, cleaning and evaluation. Refer to the CSA Standard Z94.4-M1982, "Selection, Care and Use of Respirators"⁽²¹⁾.

Respiratory Protection Guidelines

Jurisdictions which have specific regulations for non-crystalline silicas may also require specific types of respiratory protection. The requirements depend on the concentration of crystalline silica present and range from single-use disposable respirators to supplied-air respirators.

Since there may be some variation in these requirements, obtain specific information from the appropriate government agency in each jurisdiction.

In all cases, only NIOSH (National Institute for Occupational Safety and Health) or MSHA (Mining Safety and Health Administration) approved respirators should be used.

Eye/Face Protection

Use safety glasses suitable for dust protection.

VII. STORAGE AND HANDLING

Storage Conditions

Whenever possible, store non-crystalline silicas in sealed containers or in enclosed areas.

Handling

Non-crystalline silicas should be handled so as to minimize the amount of airborne dust (e.g. use wet processes or enclosed handling systems). Use in minimal quantities in designed areas with adequate ventilation. Use suitable, labelled containers, keep closed when not in use and protect from damage.

VIII FIRST AID

Eye Contact

If irritation occurs, immediately flush the contaminated eye(s) with lukewarm, gently flowing water for at least 10 minutes holding the eyelids open. If the irritation persists, obtain medical attention.



IX. CLEANUP AND DISPOSAL

Cleanup

Do not dry-sweep non-crystalline silicas. Whenever possible, wet down with a water spray to minimize the amount of dust that becomes airborne.

Disposal

Review federal, provincial and local government requirements before disposal. Disposal by secure landfill may be acceptable.



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Note: Additional references on this subject are available from CCOHS upon request.



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This summary was prepared at the Canadian Centre for Occupational Health and Safety (CCOHS) and is intended primarily as a source of information for persons who work with or may be occupationally exposed to this material. The information selected for inclusion is believed to be reliable and generally relevant to occupational health. Other information may be available which bears on particular work situations. The scientific data in many areas are limited and may allow a variety of interpretations. Additional information, corrections, comments and questions are welcome, and should be addressed to the Inquiries Service, CCOHS, 250 Main Street East, Hamilton, Ontario, L8N 1H6, (416) 572-2981; toll free 1-800-263-8276.

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